THE ROLE OF LANGUAGE IN BEHAVIOR

Technical Report Number 6

VISUAL DURATION THRESHOLD AS A FUNCTION OF WORD FREQUENCY: A REPLICATION[1]

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Word frequency as determined by counts of selected groups of texts has been shown to be an important variable in determining the duration threshold for isolated words which are presented tachistoscopically. Howes (1) has shown that even when legibility of single letters, letter pairs, etc. are not controlled, correlations on the order of -.65 or -.75 may be found for duration threshold time and the logarithm of the frequency of words as given in the Thorndike-Lorge tables (8). This finding has been of great importance in the criticism of several experiments which presumably demonstrated the effect of values and needs on perception. (See 3, 6, and an analogous example in audition (2)).

Solomon has attempted to examine this perception time and frequency relationship in a more rigorous setting in which word frequency could be directly controlled instead of being estimated from relatively crude word-count data. This experiment which has been reported by Howes (1) and by Miller (4) demonstrated an extremely high relationship (-.96) between the two variables.

In view of the importance of this relationship to further research in the area of perception and verbal behavior, the present experiment was performed to see if the relationship would prove to be stable under slightly different conditions.

Method. The experimental procedure was identical with Solomon's except as noted below. Ten experimental words were selected. In this study the words were five-letter "paralogs" (taken from the portion of Dunlap's list reprinted in Woodworth (9)) in place of the seven-letter Turkish words used by Solomon. A pack of 100 cards each bearing one word was made up for each subject. In each pack two of the words appeared 25 times; two appeared 10 times; two appeared 5 times; two appeared twice and two appeared once, making a total of 86 words. Fourteen dummy words were added to make the total of 100. Each of the experimental words was used at each frequency level in a counterbalanced design. The order of presentation within a deck was random.

Fifteen students in an introductory psychology class were used as subjects as compared to the five subjects used by Solomon. Each subject was told that these were Turkish words and was asked to spell and pronounce the words on each card in his deck. Following this the subject was left alone to read unrelated

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1. This study is part of a larger series of studies of verbal behavior being conducted at the University of Minnesota. This series is being sponsored by the Office of Naval Research (Contract No. N8 onr-66216) under its policy of encouraging basic research.

material for 20 minutes. At the end of this time he was taken to a different room in which the perception test was given. Four practice paralogs were used as a warmup and then the ten experimental words were given in a predetermined sequence. Because of time limitations it was not possible in this experiment to interpose other paralogs in the test sequence as Solomon had done. While it might be expected that this procedure was transparent and led to the Ss "guessing" out of a diminishing pool of possible words, it does not appear to have affected the results as the analysis below indicates.

Tachistoscopic exposures of each word began at 30ms. Successive exposures increased in steps of 10 or 20 ms up to 200 ms; in steps of 20 or 30 ms up to 450 ms and in steps of 50 ms beyond that point. (Since Solomon's procedure has not been reported this follows the procedure of Howes (1)). The duration threshold time recorded was the exposure time at which the S first correctly identified the test word. On both the cards and the tachistoscopic material the words were typed in capital letters.

At the end of the experiment, Ss were allowed to ask questions and comment. They appeared to have little conception of the aims of the experiment but were concerned as to whether they were giving a good performance.

Results. The data were analyzed to obtain the mean exposure times for each frequency of presentation in the deck of 100 cards. These data are presented in Table I. The correlation between the mean exposure time and the logarithm of the frequency of presentation was found to be -.99 which emphatically confirms the work of Solomon and Howes. This relationship is shown in Figure 1 with the approximate linear fit indicated.

TABLE I

Mean Exposure Time for Each Frequency Class

Frequency of Appearance in Deck of 100 Cards	Mean Exposure Time at Recognition
25	168 ms
10	203 ms
5	221 ms
2	271 ms
1	289 ms

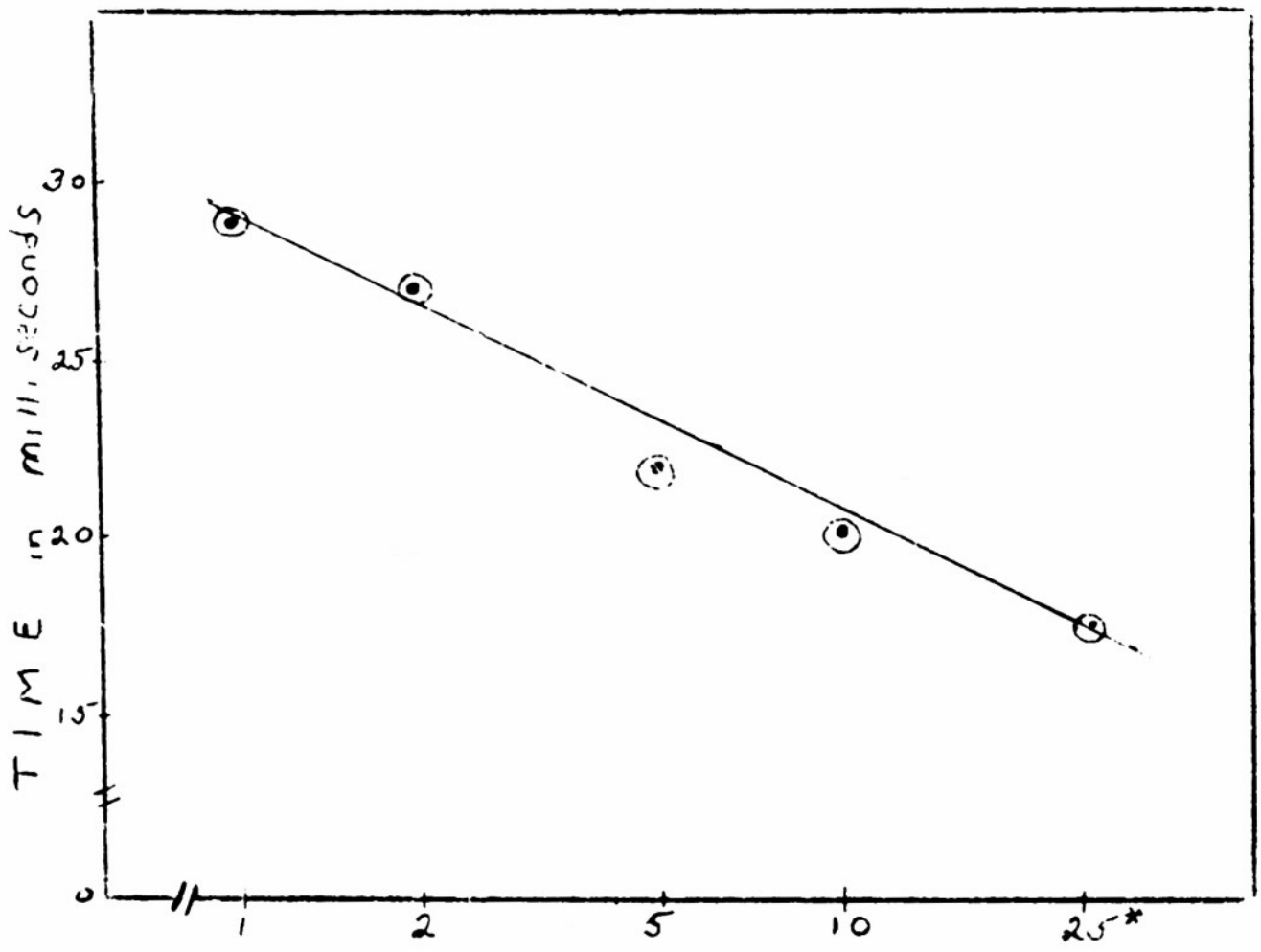

FIGURE 1

TACHISTOSCOPIC RECOGNITION TIME

AS A FUNCTION OF WORD FREQUENCY

$r = -.99$

* Distances on the X-axis are logarithms of the frequencies.

Correlations for individual Ss are given in Table II. Here each frequency class was represented by only two words and, of course, no counterbalancing to eliminate the effects of individual word legibility, order, etc. was possible. The median individual correlation was found to be -.43 which indicates a rather marked effect of frequency even when many other variables are uncontrolled and the single case is considered.

TABLE II

Correlations for Individual Subjects Between Mean Exposure Time and Logarithm of Frequency of Appearance

+ .30	- .40	- .53
- .14	- .41	- .66
- .16	- .43	- .66
- .31	- .44	- .71
- .39	- .49	- .78

The possibility that the relationship somehow rests on the subject's "awareness" of the experimental aims or on the elimination of alternative responses as the test words are run may be examined by a consideration of (1) the data for the first test word presented, (2) a comparison of the exposure times required for the first and last words, and (3) a consideration of the results when they are placed in an information theory frame of reference.

The average recognition time of the first word in each of the sets of trials may be grouped by the frequency classes. This provides three entries in each of the classes. The average exposure times are given in Table III. It may be seen that these averages approximate the overall averages as closely as could be expected with this small number of cases.

TABLE III

Mean Exposure Time for Each Frequency Class for the First Test Word Only

Frequency of Appearance in Deck of 100 Cards	Mean Exposure Time at Recognition
25	160 ms
10	187 ms
5	273 ms
2	270 ms
1	287 ms

A comparison of the first and last words in the test series shows that the last words were recognized, on the average, only 30 ms faster than the first words. Since Howes finds evidence that practice effects can be found in similar experiments even up to 60 trials, it seems quite likely that this difference may be attributed to the practice effect of the series. There does not appear to be any such great difference as might arise if the subjects were eliminating alternatives.

A conversion of these data into information theory terms is interesting in this connection and in its own right. If the perception situation is considered as a communication channel through which symbols are being transmitted to the subject as a destination the known prior frequency of these symbols may be tested as an index of the amount of "information" they convey. A highly frequent symbol (one which has a high probability of occurring) conveys very little "information", that is to say, it is highly predictable. An infrequent symbol conversely carries a great deal of "information." (5) This may be expressed as the number of binary choices necessary to select the symbol by the formula $H = -\log_2 p$ where p is the probability of the symbol. When this is done we may represent each frequency class by a figure showing the amount of "information" which is attached to a member of that class. These data are given in Table IV since this manner of expressing the data is a simple transformation of the first measure used, the correlation between "information" and threshold time is the same as the first correlation with the sign changed. This may now be interpreted as follows: As the amount of "information" per symbol increases, the duration threshold time increases linearly. Since this is the kind of relationship we should expect to find in a communication situation in which the probability of a given symbol occurring is the same on every occasion, it also provides support for the argument that elimination of alternatives did not play an important role in this experiment.

TABLE IV

Mean Exposure Time for each Information Class

Amount of Information per Symbol	Mean Exposure Time at Recognition
2.000 bits	168 ms
3.322 bits	203 ms
4.322 bits	221 ms
5.644 bits	271 ms
6.644 bits	289 ms

The data may be expressed by an equation in the form $t = c + kH$ where t is the duration threshold in ms, c is a constant expressing the general time lag in perception (a sort of "deadtime"), k is the increment in perception time

for each additional unit of "information", and H is the "information" in a given symbol expressed in bits. In this experiment c equals 128 ms and k equals 23 ms per bit. As an additional binary choice is necessary to "select" a given symbol, the perception time for that symbol increases by 23 ms. It is tempting to suggest that these constants may have utility beyond the description of this particular set of data but that, of course, is a matter for further experimentation.

Discussion. The tachistoscopic technique as used here appears to be a very stable and sensitive one in which a clear relationship has been demonstrated between prior frequency or familiarity of words and their recognition time. This further stresses the fact that studies on perception cannot overlook frequency as a major factor in determining visual thresholds. The relationship also may be used to good advantage by investigators of word frequencies and the related problems of meanings, interests and values. The technique may offer a means of investigating individual's states of familiarity with verbal symbols which have previously been difficult to ascertain quantitatively.

Whether the rephrasing of the results in terms of information theory is valuable or not depends, of course, on whether it leads to fruitful hypotheses which were not previously obvious. It has been suggested by Takada (7), for example, that research in discriminative reaction time (which can be predicted by similar equations involving the number of alternatives available) be extended to examine the hypothesis that channel capacity (bits of information per second) has a constant value for each individual. The same suggestion should be examined in this situation. Inspection of Solomon's data along with the findings of this experiment suggests that the hypothesis may not prove to be true but the necessary experiments should, of course, be conducted. Other hypotheses suggest themselves and further work by the writers and others will be directed toward examining them.

Summary. Solomon presented Ss with a deck of cards bearing unfamiliar words with different frequencies of appearance in the deck. After a period of irrelevant activity, the Ss were tested tachistoscopically to determine the duration threshold of the words at each frequency level. He found a correlation of - .96 between mean duration threshold and the logarithm of the frequency of presentation. This study repeated Solomon's work with slight variations (paralogs instead of Turkish words, 15 instead of 5 Ss, no filler words in the tachistoscopic test sequence, and other minor differences). The results confirm Solomon's findings. The correlation between average duration threshold and the logarithm of the frequency of presentation was - .99. Individual correlations were reported. The hypothesis that this might be due to elimination of possible alternatives was considered and discarded. Applications of the technique and the relevance of the rephrasing of the results in terms of information theory were discussed.

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